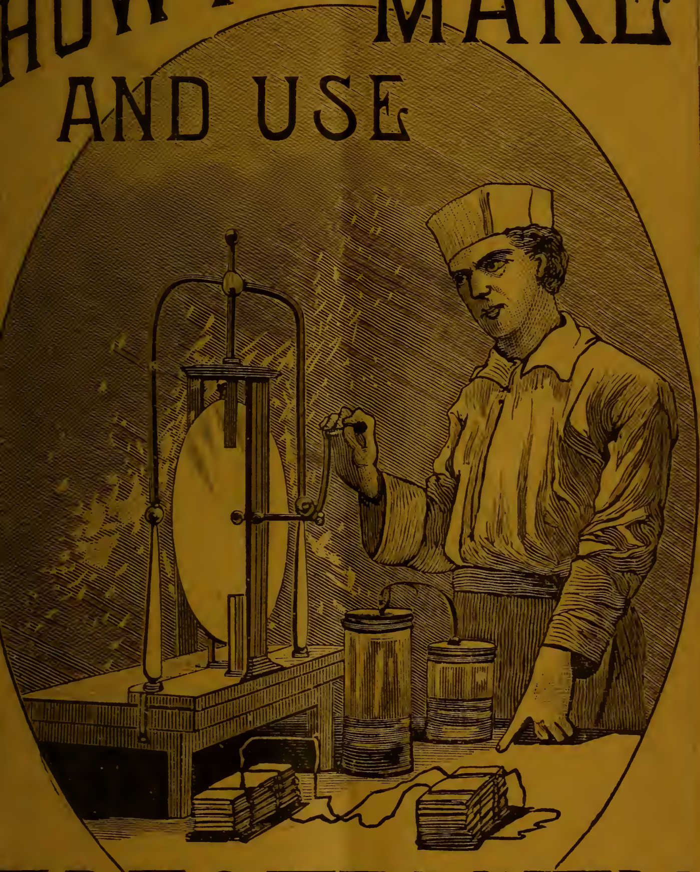
HOW TO MAKE AND USE



ELECTRICITY

HOW TO
Make and Use Electricity.

A Description of the Wonderful Uses of Electricity and Electro-Magnetism, Together with Full Instructions for Making Electric Toys, Batteries, Etc., Etc.

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Containing Over Fifty Illustrations.

NEW YORK:
FRANK TOUSEY, Publisher,
34 AND 36 NORTH MOORE ST.

HOW TO MAKE

AND

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CHAPTER I.

FRICTIONAL ELECTRICITY.

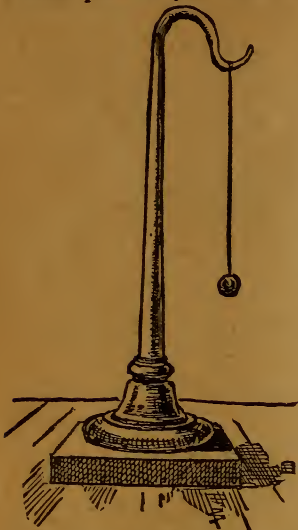
ELECTRICITY, that great and marvelous agent in nature, of whom we hear and see so much, and of whose composition we know so little, is virtually to be found everywhere and in everything living or inert.

To give an accurate definition of this agent is beyond the power of any living man. We simply know that it exists and that it is subject to certain rules of which we will speak later. I desire simply to give the BOYS OF NEW YORK a few hints and instructions to enable them to make use of this wonderful agent for their own amusement.

The term electricity is used to denote both the unknown *cause* of electrical phenomena, and the *science* which treats of electrical phenomena and their causes. The most general effect by which the presence of electricity is manifested is *attraction*. Thus, if you take an ordinary cylindrical lamp chimney and rub it with a dry silk handkerchief or woolen cloth, it will attract small bits of paper, feathers and cotton. A very pleasing experiment of this kind may be performed by laying two rows of bits of tissue paper upon a table, and passing your chimney slowly over them at a height of about one inch. The bits of paper will all scramble toward the chimney and will adhere to it for a short time.

There are some bodies through which electricity will not pass; such bodies are *non-conductors*. Those through which the current passes readily are called *conductors*. An example

of the above will be found in the following experiment: Take a small piece of pith from an elder stalk and attach it to the wooden stand, as shown in this cut, by means of a small filament of silk thread. The pith should be about the size of a tomato seed, and the silk may be obtained by unwinding a silk thread and taking out one of the thin strands. Glue the pith ball to the silk thread by means of common mucilage, and after you have thoroughly rubbed your lamp chimney, gradually approach it to the pith ball and note the result. Every time you near the ball it will move away from the glass, thus indicating that a non-conductor will repel a good conductor which has been charged by the same kind of electricity.



In case there should be no elder stalks at hand, bits of cotton, feathers or cork will answer the purpose. This experiment may be performed on a large scale by making a spider out of cork, painting it black and passing black thread through the body for legs. After the spider has been attached to the stand in the same manner as in the preceding experiment, take a large gallon bottle, and electrify it by rubbing hard for several minutes. The bottle will become electrified much more readily if it has been previously warmed.

A sheet of common white writing paper if warmed and rubbed vigorously with the back of a rubber comb will adhere to the wall for some time; or if placed near the cheek of a person would produce a peculiar crawling sen-

sation on the skin, resembling that produced by a cobweb. In this latter case, the paper should be held within a quarter of an inch from the face. This is a neat little trick for boys to play upon their schoolmates who sit in the bench before them.

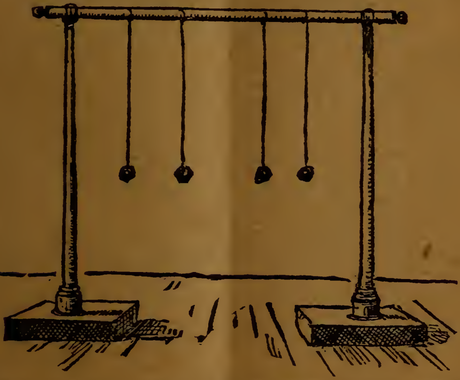
All the above experiments simply indicate the presence of electricity in these bodies, and also furnish proof for the fact that it generally makes itself known by either *attraction* or *repulsion.*

Although friction is the most common and by far the most extensive means of exciting bodies, yet it is not the only means.

Electricity is manifested during the changes of state in bodies, such as liquefaction and congealation, evaporation and condensation. Some bodies even are excited by mere pressure; others by the contact or separation of different surfaces. Most chemical combinations and decompositions are also attended by the evolution of electricity.

If we rub a piece of amber, sealing-wax or any other resinous substance on dry woolen cloth or fur, or silk, and bring it toward the pith-ball, it will be repelled. But, if we take a piece of iron, brass, or copper, and rubbing it thoroughly, bring it close to the ball, what will it do? It will do nothing at all, for these substances are such good conductors, that so soon as the electricity is generated, it passes through the hand and body to the ground, and is lost.

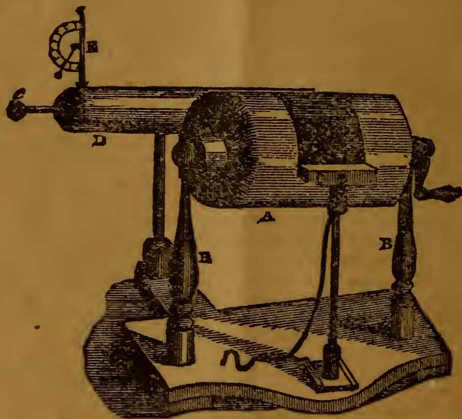
You have seen that if a glass rod or chimney is excited by rubbing, it will *repel* a pith ball. But if you rub a piece of sealing wax with a dry woolen cloth, it will attract the pith ball. Hence, if you hold a glass on one side and a piece of sealing wax on the other side of the ball, it will swing from one to the other like the pendulum of a clock. This proves that there are



two kinds of electricity, viz: positive and negative. That which attracts the ball is positive, and that which repels it is negative.

Make a stand of light wood about six inches high by four

inches wide, shaped like the illustration above, and suspend therefrom three or four pith balls with silk threads fastened to the cross piece. Now touch the end ball with your lamp chimney and each one of the balls in succession, and you will find that they will repel each other. But if you touch some of them with sealing wax, and some with glass, you will find that they attract each other. The best way, however, to generate frictional electricity is by means of the Cylinder Machine, which any boy of average intelligence may construct for himself; and many are the amusements which may be derived from it.



The principal parts belonging to this machine are called the cylinder (A), the frame (B B), the rubber (C) and the conductor (D). For the cylinder (A), take a large, smooth candy jar and cement a circular piece of quarter inch board over the top, where the lid ought to be. Glue a smaller circular piece to the bottom of the jar, and drive a round piece of iron (1-8 by 3 inches) into the wood at both ends to act as an axle. This axle is fitted accurately into holes previously made in the uprights (B. B), so as to turn without waddling.

The woodwork should be coated with varnish. The rubber (C) consists of a leather cushion or pad stuffed with hair like the padding of a saddle. To the top of the pad is sewed a piece of silk half as wide as the cylinder is long, and extending over the top of it to within an inch of the points of the conductor, to be mentioned presently.

The rubber should be coated with an amalgam of equal parts of mercury, powdered zinc and tin rubbed up together. The rubber should be made to fit closely to the cylinder, in order that it may rub the cylinder equally when it is turned by means of the crank. The crank is attached to the axle at either

end. The pillar upon which the rubber rests should be insulated by placing a piece of india rubber between it and the base board.

The conductor (D) is a hollow cylinder of brass or copper, mounted upon an upright with a broad base, so as to balance it evenly, and insulated with india rubber. Through the back of the pad runs a screw so far as to almost touch the glass jar when it revolves, and to this screw attach a brass or iron chain, which is allowed to hang down on the base board. Into one end of the conductor bore a hole and insert a copper wire of about five inches in length (c). The condenser should be placed about one foot distant from the cylinder. Make a rake by soldering five or six pieces of inch wire to a larger wire of the same width as the cylinder, and fasten it to the conductor by means of a heavy copper wire.

The points of the rake should be about one eighth of an inch distant from the cylinder. In order to operate the machine, turn the crank violently, when it will be noticed that sparks will jump from the cylinder to the points of the rake, and in this manner will charge the conductor. In making this machine, care must be taken to use nothing but well-seasoned, dry lumber, and to fit the axle accurately in the supports, otherwise the cylinder will wabble when it is turned and will produce no current at all. If properly made this machine will generate an enormous quantity of electricity, and many pleasing and instructive experiments may be performed with it. In our next chapter I will enumerate these and also show how to make a galvanic battery and the uses to which it may be put.

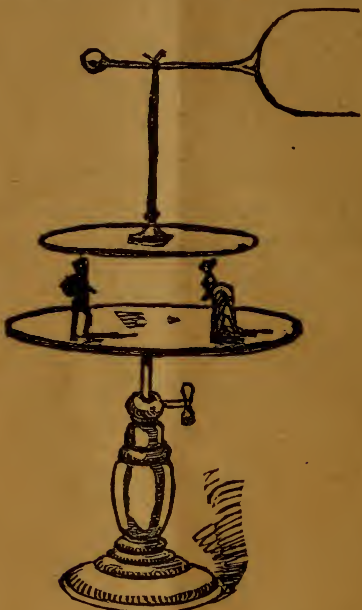
CHAPTER II.

FRICTIONAL ELECTRICITY.

After having made our friction machine, we are ready to perform a number of experiments which will demonstrate the relation between positive and negative currents. But during all this discussion we must bear in mind that no electrical phenomena can take place without a *circuit*. It matters not whether we deal with primary, induced or frictional currents; we must always have a circuit to accomplish any purpose. It will be well for the learner to bear this in mind, as it will often explain a failure.

Figure 1 represents two plates of copper or brass, of which the upper is suspended from the prime conductor by a metallic chain, and the lower rests on a stand which may be elevated or depressed at pleasure. If the stand is insulated, the effect of the insulation may be taken off by letting a chain or tinsel cord hang from a nail in the side of the table on which the plate rests, to the floor. The images are formed of light paper (gilt paper is best) or of elder pitch, dressed so as to represent living figures. On turning the crank of the machine, the upper plate becomes electrified and lifts the images toward it. When they come near it they become similarly electrified, are repelled, and

descend to the lower plate, and thus perform a kind of dance, which, if well managed, may be made to imitate strikingly the motions of real life. Sometimes, when the images do not dance readily on their feet, they will still dance on their heads. Breathing on them sometimes makes them dance more lively, by making them better conductors; and a *certain* amount of electricity, neither too much nor too little, is to be supplied by varying the

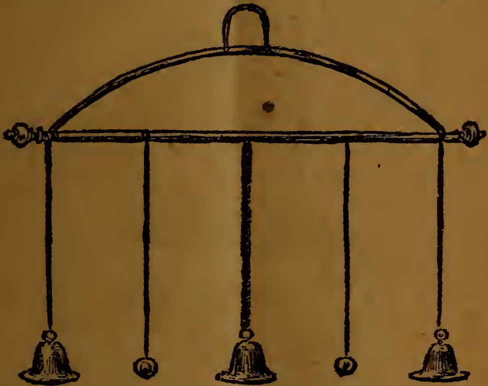


rate of turning in the machine, so as to hit the exact point which is most favorable.

In this instance, the upper plate communicates its positive electricity to the figures, and they, when they are electrified by the same current, are repelled instead of attracted, thus giving rise to that Indian war-dance which they perform. Several figures may be dressed up as men and women or as animals, and the performance may be varied so as to suit the taste and fancy of individuals.

Fig. 2 represents a chime of bells which may be increased to any number desirable from two to ten or more. If the bells are of different tones, the effect will be more pleasing. Three bells are hung side by side to the prime conductor. The two outer bells are suspended by metallic chains, which connect them

with the prime conductor, while the inner bell is suspended by a silk thread which insulates it; but from its center a fine chain or tinsel cord falls on the table so as to connect it with the ground. The clappers—two in number—are hung by silk threads between the bells and consist of small bits of copper, iron or brass. Now, when the machine is turned, the outer bells immediately become electrified and attract the clappers, which no sooner come into contact with them than they imbibe the same kind of electricity and are repelled and go to the central bell where they discharge their current and return for more; thus



keeping the bells constantly ringing. A very moderate amount of electricity is sufficient for this experiment.

This also demonstrates very clearly that like currents *repel*, and opposite currents *attract*. It also shows that a body will hold just so much current, and no more.

The best experiment of this kind is performed by placing a glass vessel full of water upon a table, and allowing a chain, which is attached to the prime conductor, to hang in the water, in which the figure of a metallic swan is floating. Whenever the finger is approached to the swan, it follows it wherever it goes.

We now come to an instrument which, at the time of its discovery, caused great admiration and astonishment, and was looked upon with superstitious awe by the multitude. But at this age of enlightenment, the Leyden jar is considered a commonplace affair, and is simply used to demonstrate the laws of frictional electricity.

The Leyden jar derives its name from the place of its discovery. In the year 1746, while some philosophers of Leyden were performing electrical experiments, one of them happened to hold in one hand a tumbler partly filled with water to a wire connected with the prime conductor of a friction machine. When the water was supposed to be sufficiently electrified, he

attempted, with the other hand, to detach the wire from the machine; but as soon as he touched it, he received a powerful electric shock.

It was by imitating this arrangement that the Leyden jar was constructed; for here was a glass cylinder, having good conductors on both sides, viz., the hand on the outside, and the water on the inside, which were prevented from communicating with each other by the non-conducting power of the glass. A metallic coating, as tin-foil or sheet lead, was substituted for the two con-

ductors, and a jar for the glass cylinder, and thus the electrical jar was constructed. In an age less enlightened than the present, and less familiar with the wonders of philosophy and chemistry, the striking and peculiar effects of electricity, as exhibited by the Leyden jar, would naturally excite great admiration and astonishment. Accordingly, showmen traveled with the apparatus through the principal cities of Europe, and probably no object of philosophical curiosity ever drew together greater crowds of spectators. It was this astonishing experiment which gave eclat to electricity. Everybody was eager to see and feel the experiment.

Coat a green glass quart fruit-jar within and without,

for about twothirds its length with tin foil, using flour paste Close the mouth of the jar with a cork, and pour sealing-wax over it. Through the cork pass a stout brass or copper wire till it touches the inner foil. Cast a lead bullet (a) on the exposed end of the wire. Clean, warm and varnish the exposed glass surface of the jar, and *thoroughly dry* it, and it is ready for use.

The jar may be charged by connecting its outer coating with the earth and bringing the leaden ball close to the prime conductor, or by connecting one of its coatings with the prime

conductor (+) and the other with the chain (—). To discharge the jar connect the outer coating with the knob of the jar. To avoid a shock in doing so prepare a discharger as follows: Through the cork of a soda-water bottle pass a stout brass semi-circular wire. Cast on each of its ends a lead bullet. Place the cork in the bottle, and use it as a handle. When it is desirable to discharge the Leyden jar touch the outer coating with one ball and the knob of the jar with the other. A bright spark will pass from the knob to the ball and the jar will discharge itself with a loud report.

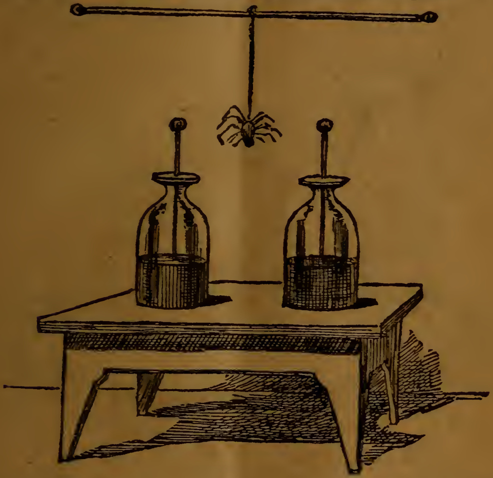
The charge of a Leyden jar may be retained for a very long time. If the surfaces be well separated from each other the charge remains for many days, or even weeks. The charge is usually dissipated by particles of dust in motion or other conducting substances in the atmosphere from one of the coatings

to the other, or by the uncoated interval becoming moist and losing its insulating power; consequently a jar will retain its charge longer in dry than in damp weather. It is best to make three or four Leyden jars, since there are some experiments which require the exclusive use of a jar.

Figure 5 represents two Leyden jars, one charged positively and the other negatively, and placed side by side on a table. Between them is suspended by a silk thread an image of a spider, having a body of elder pith and legs of black linen thread. This image is alternately attracted and repelled between the two jars, thus very strikingly showing the opposite characters of the two electricities.

In this ingenious apparatus (Fig. 6), three little birds, made

of pith ball or light paper, and painted to suit the taste, are kept suspended by their mutual repulsion whilst the jar is charging; but when the charge arrives a certain degree of intensity, a spark will pass from the knob of the gun of the sportsman, and the birds fall instantly. The sportsman should be made of tin, and the gun of copper and placed upon a small piece of board.



The birds are attached to the wire by means of silk threads, and the two wires are inserted into the cork of a Leyden jar. The jar should not be fastened to the board. Charge the jar with a friction machine and move its free knob up to the gun of the sportsman. This finishes the subject of the Leyden jar, and leads us to a short explanation of the "Electrophorus," which we will give next time.

CHAPTER III.

ELECTROPHORUS AND CURRENT ELECTRICITY.

In case it should be impossible to make a friction machine, the electrophorus will answer all ordinary purposes. It is made in the following manner:

On a circular disk of sheet-iron or tin 8 inches in diameter cement a circular disk of vulcanite 7 inches in diameter.

To the center of another circular disk of tin 5 inches in diameter, (Fig. 1) apply with heat one end of a stick of sealing-wax for a handle. Now strike the surface of the vulcanite a few times with a cat's fur or a fox-tail; it will become electrified with negative (—) electricity. Then place the tin disk on the

vulcanite; the negative electricity of the vulcanite will polarize the disk, inducing positive (†) electricity on its lower surface and — electricity on its upper surface. Now place a finger on the disk. The — electricity will escape through your body to the earth, but the † electricity will remain on the disk, held by the — electricity of the vulcanite. Finally, raise the disk by its insulating handle. Removed from the influence of the — elec-

tricity on the vulcanite, the † electricity of the disk is now free, and if a knuckle of one of your hands (Fig. 2) is brought near it, a bright spark will pass from it to your hand, and it will become discharged.

The disk may be charged and discharged in the same manner a great number of times without again whipping the vulcanite with the fur.

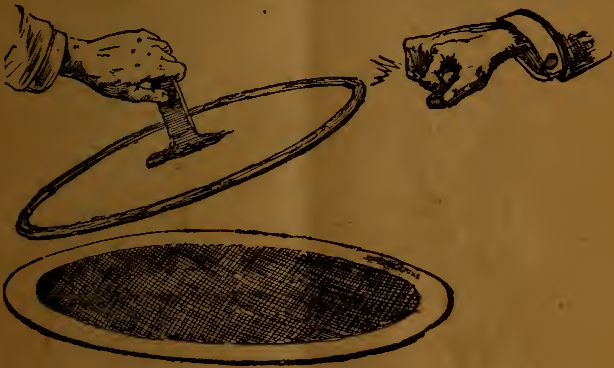
A Leyden Jar may be charged in the same manner a great number of times without recharging the electrophorus. This apparatus will take the place of a friction machine, and most of the experiments mentioned in connection with the same may be performed with the electrophorus. Before taking up current electricity there is one more amusing experiment which may be performed with any instrument.

Prepare an insulated stool (Fig. 3.) by placing a square board on four *dry* and *clean* glass tumblers used as legs. Let a person, whom we will call John, stand on this stool, and let a person, James, strike John a few times with a cat's fur. (Borrow the fur from some cat on a moonlight night). Then let James bring the knuckle of a finger near to some part of John's person, nose, chin or hand; an electric spark will pass between the two, and a slight shock will be felt by both. In most cases the spark will be very large.

An experiment that will cause great astonishment may be performed in a dark room in the following manner: Let the person

who is to perform the experiment take off his shoes and put on a pair of dry woolen socks. Now let him scrape both feet violently on the carpet, sliding one foot after the other (imitating roller skating), and after this has been done for a few minutes approach a knuckle of the hand to a gas jet, and the gas will immediately catch fire. A woolen carpet is necessary in this experiment.

I have performed this experiment several times, and it never



fails to leave an impression of the supernatural upon the minds of those who are not acquainted with the laws of electric phenomena. It may be well to remark that this experiment cannot be performed by every person.

We now come to that portion of electrical science which has been so remarkably developed within the last few years—namely, current electricity, or electricity as generated by batteries or magnetism. In the frictional, electricity is generated by means of friction between two substances; in the current it is generated by means of a chemical decomposition of metals.

Batteries are vessels containing a chemical solution in which two metals, or a metal and a vegetable substance, are immersed. In current electricity also we find two kinds of fluid—the positive and the negative. To demonstrate this chemical action, take a strip of sheet copper and a strip of sheet zinc, each about six inches long and two inches wide; take also a tumbler two-thirds full of water, and to it add about two tablespoonfuls of sulphuric acid. (See fig. 4.) Place the zinc and copper strips in the glass, and allow the exposed ends to touch; instantly bubbles of gas collect on the surface of the copper, break away from it, rise to the surface of the liquid, and are rapidly replaced by others. These are bubbles of hydrogen gas, and may be collected and burned. It is soon found that the zinc wastes away, or is dissolved in the liquid. In this instance the sulphuric acid acts upon the zinc,

forming sulphate of zinc, which, being soluble in water, is raedily dissolved. The action upon the copper is the same, but not so strong. Sulphate of copper is formed in the same mannre. By means of this chemical combination electricity is produced, and hydrogen gas is liberated. This experiment also proves that zinc is composed largely of hydrogen gas.

Withdraw the zinc from the liquid, and while it is yet wet rub a little mercury over its surface, so that it may become completely wet with the liquid metal. Now repeat the above experiment. First, it is found that the zinc, when alone in the liquid, is not affected by it, and no bubbles of gas are formed. But when the two metals are immersed in the liquid, and are brought into contact, bubbles of gas quickly appear on the copper as before, but none appear on the zinc, although it will be found that the zinc still wastes away, whilst the copper remains apparently unchanged. Instead of placing the metals in contact, connect them by means of a copper wire, the points of contact being clean; the bubbles are given off at the copper as before. Cut the connecting wire at any point, or separate it from the zinc or copper, all evolution of bubbles ceases, but begins again the instant the contact is made.

Interpose between the connecting wires a piece of

paper, wood or rubber, or use some one of these instead of a wire to connect the two plates; no action appears in the glass. Thus it is evident that there must be a connection, and that too of a particular kind, between the two metals in order that action may occur. The connecting wire, then, is an important factor in the changes that occur, and it seems altogether that some influence is exerted by the metals upon one another through the wire, in other words, that something unusual is going on in the wire when so used.

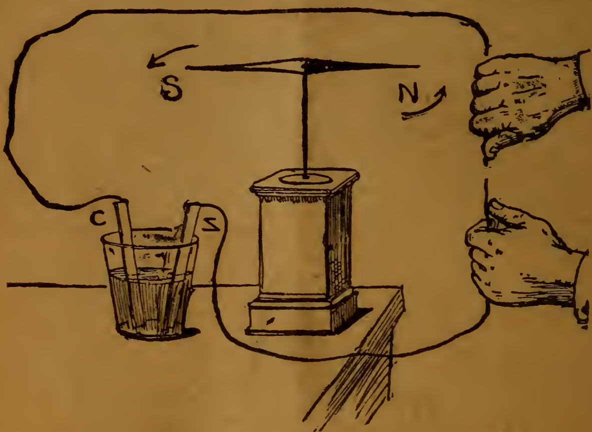
Now the question arises: Is that action confined to the cell, or is it also manifest in the wire which connects the two elements of the cell. (The zinc and copper are called *elements*, and the tumbler is called a *cell.*) In order to discover what the wire contains, we will try the following experiment.

Take an ordinary compass, or poise a magnetic needle at its center, either by pivot, as in Figure 5, or by a fine untwisted silk thread, and arrange the connecting wires as in the figure. The needle when at rest points north and south. The connecting wire being over the needle, and parallel to it, bring the two extremities into contact; instantly the needle

turns on its axis, tending to place itself at right angles to the wire, and, after a few vibrations, takes up a permanent position, forming an angle with the wire. This deviation from its normal position is called a *deflection of the needle.* Separate the two extremities of the wire, and the needle will swing back to the usual position. If a piece of paper is interposed be-

tween the ends of the wire, no deflection of the needle will occur.

Take a large iron nail, and plunge one end of it into iron filings, and then remove it; no filings cling to the nail. Next, wrap a piece of paper around the nail, leaving the ends exposed, and wind around it 20 or more turns of copper wire, taking pains that the coils do not touch each other. Now con-



nect the wire with the copper and zinc as before, so that there will be a continuous connection from one strip to the other through the coil, and dip one end of the nail again into the filings, raise the nail and a considerable quantity of filings clings to the nail. The copper strip is frequently called the negative plate, and the zinc strip the positive plate, and the end of any conductor connected with the copper or negative plate is called the positive pole, or electrode, while the end connected with the zinc or positive plate is called the negative pole or electrode. Therefore if we bring together the † and — electrodes, the current passes from the former to the latter, across the junction; and generally that plate and that electrode is † from which the current goes, and that plate and that electrode is — to which the current goes.

+ Zinc Iron Tin Lead Copper Silver Platinum Carbon —

————————————————————>

If, instead of copper, we had used two zinc plates in our experiments above, there would have been generated two opposite currents which would neutralize each other and thus give no

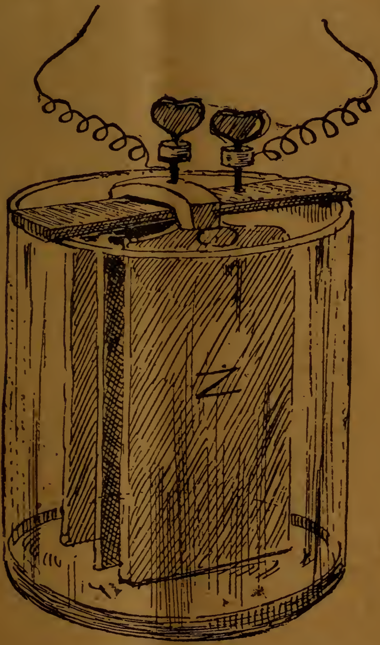
result. In the preceding table the substances are so arranged that those at the head and bottom work best together.

It will be seen, therefore, that zinc and platinum are the two metals best adapted to give a strong current. Silver and copper come next. In making a battery, the strength may be computed by the above list.

CHAPTER IV.

BATTERIES.

FROM the table given in the last chapter, it will be seen that carbon and zinc, and copper and zinc, make good combinations



for both powerful and lasting batteries. Of course, the strength and duration of a current depend largely upon the solution used. Zinc is used in more batteries than any other element. All commercial zinc contains impurities, such as carbon, iron, etc. If a piece of zinc, containing a particle of iron on its surface, is immersed in dilute sulphuric acid, the particle of iron with the

zinc will form numerous voltaic circuits, and a transfer of electricity along the surface will take place. This action between the zinc and its impurities divert so much from the regular battery current, and thereby weakens it. In addition to this, it occasions a great waste of chemicals, because, when the regular circuit is broken, this *local action*, as it is called, still continues. If pure zinc were available, no local action would occur at any time, and there would be no consumption of chemicals, except at times when the circuit is closed. If mercury is rubbed over the surface of the zinc, after the latter has been dipped in acid to clean its surface, the mercury dissolves a portion of the zinc, forming with it a semi-liquid amalgam which covers up its impurities, and the amalgamated zinc then acts like pure zinc, lasting for a much longer period.

But there is another drawback which causes electricians much trouble, and that is the polarization of plates.

When zinc and copper elements are first placed in dilute acid, a very good current of electricity is produced; but the current soon becomes feeble. But the cause is soon discovered. The liberated hydrogen adheres very strongly to the copper, as there is nothing for it to unite with chemically; and therefore the plate is very soon visibly covered with bubbles which may be scraped off with a feather or swab, but only to have the same thing repeated. This coating of bubbles impedes the flow of electricity and diminishes the current. This action is called polarization of plates. Very many methods both mechanical and chemical, have been devised for remedying this evil.

The following are the best and most widely known batteries, and all of them may be readily made without much trouble. Instead of a jar, a common earthen crock for a large, and a tumbler for a small battery, may be used.

The Smee battery (Figure 1) consists of a silver plate, or sometimes a lead plate, which is coated with a fine, powdery deposit of platinum which gives the surface a rough character, so that hydrogen will not readily adhere to it, suspended between two plates of zinc. The two zincs are connected with each other forming one pole and the silver or lead forms the other pole. Care must be taken to prevent the zincs from touching each other or the middle plate. The solution used in this battery consists of one part of sulphuric acid to twenty parts of water. This battery is useful in running medical coils, electroplating and generally where a strong, constant current is required. The zincs should be rubbed with mercury frequently to avoid wasting.

In the Grenet battery, the hydrogen is disposed of by means of chemical action. This action is rather complex, and will therefore, be omitted. The liquid used is a mixture of two ounces of bichromate of potassium, and one ounce of sulphuric acid dissolved in a quart of water. The zinc plate Z (Fig. 2) is suspended between two carbon plates C, C. The carbons remain in the liquid all the time. (Carbon in the form of charcoal or electric light pencils will do.)

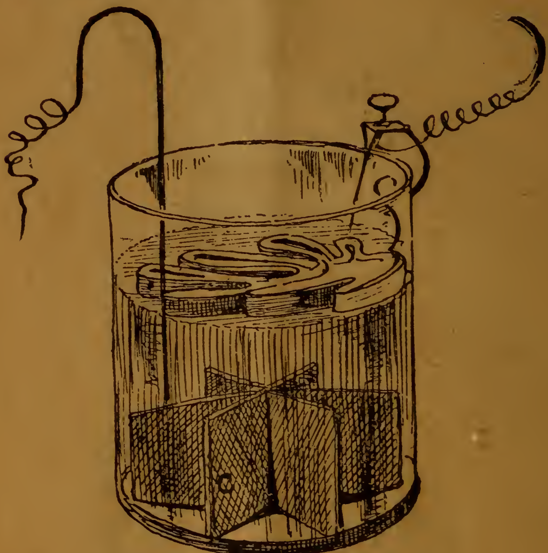
This battery gives a very energetic current for a short time,

but the liquid is soon exhausted. It is a very convenient battery, as, when not in use, we have only to draw the zinc out of the liquid by the brass stem A, and, on pushing the zinc back into the liquid, action commences again. It is well to allow the battery to "rest" for a time by withdrawing the zinc from the solution.

This is the best and most powerful form of battery known With two cells of this battery, a small two-candle incandescent lamp may be burned for 2 1-2 hours. Eighteen small cells will burn a 6-candle lamp for 1 1-2 hours. Later on I will describe a pocket battery which any boy can make and which will light a

small electric light scarf-pin. For strong currents or closed circuit work, this is by far the best form of battery. If instead of the above mentioned solution, a mixture of carbonate of ammonia and water is used, it will answer well for open circuit work with call bells, telegraph instruments, etc.

The battery principally used in this country for telegraphing is called *gravity* or "*crowfoot*" *battery.*



A copper plate, C, Figure 3, is placed on the bottom of a glass jar and covered with crystals of copper sulphate (blue vitriol), and the whole covered with water. As the vitriol dissolves its weight causes it to remain at the bottom in contact with the copper plate. The zinc crowfoot is suspended from the side of the jar by means of a notch. To start the action quickly a teaspoonful of common salt or zinc sulphate is dissolved in the water. In this battery the zinc need not be amalgamated. This is a very constant and lasting battery, requiring but little attention beyond the occasional addition of blue vitriol and cleaning the zinc about every two weeks. Two or three cells are usually sufficient to run all electrical bells in a house. One cell will run two telegraph instruments a few feet apart.

For the following experiments make a Grenet battery according to the directions given above and charge it with the solution. Introduce between the ends of the copper wire of the battery a piece of No. 30 platinum wire about one-eighth of an inch in length. If the solution in the battery is fresh the

platinum wire becomes white hot. Now stretch the platinum wire over a gas-burner, turn on the gas and light it by the heat of the wire. If lycopodium powder is strewed over cotton wool and is touched with the hot wire it will ignite.

Connect one wire to an ordinary file or rasp in a dark room, and rub the other wire over the rough surface of the file. As the wire passes over it the circuit is rapidly broken and closed, and each break causes a spark at the point where the circuit is broken. The shower of sparks that flies from the file is due to red-hot particles of iron that are projected into the air.

For the following experiment a V-shaped tube is necessary, which may be made by beating an ordinary glass tube in a Bunsen or oxy-hydrogen flame, and bending when it has acquired a cherry colored heat.

Steep some leaves of purple cabbage, the solution has a deep purple color. Dissolve a little caustic soda in water, and pour a few drops of the solution into a portion of the infusion, and the purple will be changed to green. Caustic soda

is an alkali, and cabbage infusion is turned green by alkalies only. Pour a few drops of dilute sulphuric acid into another portion of the infusion, and the purple will be changed to a red. Only acids turn purple cabbage infusion red.

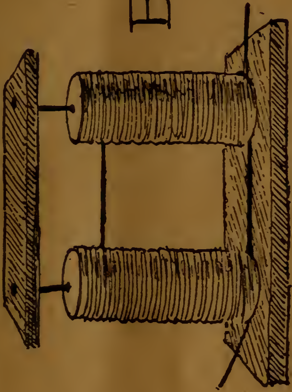
Now prepare a concentrated solution of sodium sulphate. Color the solution with a portion of the purple cabbage infusion, and partly fill the V-shaped glass tube (Fig. 4) with this liquid. Employ a battery of two Grenet cells, connecting the carbon of one battery with the zinc of the other. (See Fig. 2.) Attach to the poles of the battery wires two narrow strips of platinum, and place one of these strips in each end of the

tube, a little distance apart, so that the current will be obliged to traverse a part of the liquid. Close the circuit; bubbles of gas are immediately disengaged from the platinum strips; soon the liquid around the — pole is turned green, while that around the † pole is turned red. Evidently de-

composition of the sodium sulphate has taken place; an acid and an alkali are the results. This is called electrolysis.

Prepare a solution of ccpper sulphate, and subject it to electrolysis, as in the last experment; copper collects on the — platinum, and sulphuric acid and oxygen at the † platinum. Remove the platinum strips and introduce the copper ter-

B



a b

A

minals; copper is now deposited on the — pole as before, but the † pole wastes away.

Although we can obtain a strong current and perform many neat experiments with a battery, still electricity would

be of little value practically, were it not for the fact that it can be converted into magnetism, and from magnetism to electricity. Upon these two laws and principles are based all electrical appliances.

Obtain an insulated copper wire, wind twenty or more turns around a rod of very soft iron, four inches long by one quarter of an inch in thickness, and close the circuit. Bring a nail, (Figure 4) or other piece of iron, near the rod. The rod attracts the nail with much force, and this nail will attract other nails. The rod has acquired all the properties of a magnet. But the instant the circuit is broken, the iron loses its magnetic force, and the nails drop.

The more times the wire is wound around the rod, within a certain limit, the more powerful is it magnetized. This arrangement is called an *electro-magnet*. The rod of iron is called its *core*, and the coil of wire the *helix*. In order to take advantage of the attraction of both ends or poles of the magnet, the rod is most frequently bent in a U-shape (A, Figure 6), and then it is called a horse-shoe magnet. Sometimes two iron rods are used, connected by a rectangular piece of iron, as A, in B of Figure 6.

The method of winding is such that if the iron core of the horse-shoe were straightened, or the two spools were placed together, end to end, one would appear as a continuation of the other, a piece of soft iron, b, placed across the ends, and attracted by them, is called an *armature*. The piece of iron A is called a *back armature*.

CHAPTER V.

THERMO-ELECTRICITY.

So far in our experiments we have obtained a current of electricity by using the potential energy due to the chemical affinity of zinc and sulphuric acid, or by expending mechanical energy; but we can also get a current directly from the molecular energy that we know as heat.

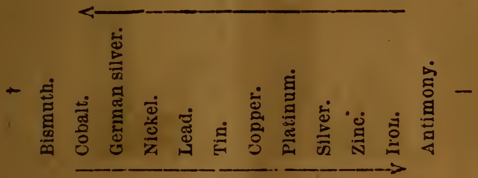
Insert in one screw cup of a sensitive galvanometer an iron wire, and in the other cup a copper, or, better, a German silver wire. Twist the other ends of the wire together, and heat them at their junction in a flame; a deflection of the needle shows that a current of electricity is traversing the wire. Place a piece of ice at their junction. A deflection in the opposite direction shows that a current now traverses the wire in the opposite direction.

These currents are named, from their origin, thermo-electric. The apparatus required for the generation of these currents is very simple, consisting merely of bars of two different metals joined at one extremity, and some means of raising or lowering their temperature at their junction, or of raising the temperature at one extremity of the pair and lowering it at the other; for the electro-motive force, and consequently the strength of the current, is nearly proportional to the difference in temperature of the two extremities of the pair. The

strength of the current is also dependent on the thermo-electric force of the metals employed.

The following thermo-electric series is so arranged that if the temperature of both junctions are near the ordinary temperature of the air, those metals farthest removed from each other give the strongest current when combined; and the current passes, when heated at their junction, from the one first named to that succeeding it. The arrows indicate the direction of the current at the heated and cold ends respectively. At high temperature the current may be reversed.

COLD.



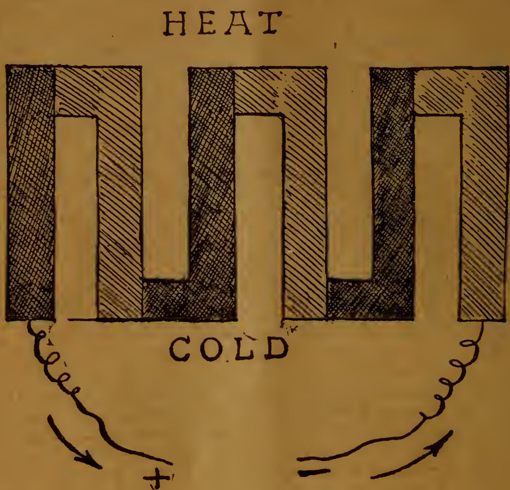
HEAT.

The electro-motive force of the thermo-electric pair is very small in comparison with that of the voltaic pair; hence the greater necessity of combining a large number of pairs with one another in series. This is done on the same principle, and in the same manner that voltaic pairs are united —viz., by joining the † metal of one pair to the — metal of another. Fig. 1 represents such an arrangement. The light bars are bismuth, and the dark ones antimony. If the source of heat is strong and near, by either conduction or convection, one face may be heated much hotter than the other, and a current equal to that from an ordinary galvanic cell is often obtained. Instruments constructed on these principles, and used as a source of electricity, are very convenient and efficient for many purposes, especially when a steady current is required with small external resistance. They are called thermo-electric batteries.

If the source of heat is feeble or distant the feeble current may serve to measure the difference of temperature between the ends of the bars turned toward the heat and the other ends, which are at the temperature of the air. The apparatus, when used for this purpose, is called a thermo-pile or a thermo-multiplier.

A combination of as many as thirty-six pairs of antimony and bismuth bars, connected with a very sensitive galvanometer, constitutes an exceedingly delicate thermoscope and thermometer. Quantities of heat, that would not perceptibly expand the mercury in an ordinary thermometer, can, by the use of a thermo-electric pile, be made to produce large deflections of the galvanometer needle. Heat radiated from the body of an insect several inches from the pile may cause a sensible deflection.

In the selection of a battery for a particular use several things must be considered. Among the most mportant of these



are the intensity of the current required, and the service required, i. e., whether continuous, temporary or occasional currents are wanted. The cost is of consequence, but that must be governed mainly by the preceding considerations. In the following table preferences are given to the several batteries by numbers in the order in which they occur against the several uses specified:

NAMES OF BATTERIES, ETC.

1. Smee.
2. Leclanche.
3. Gravity.
4. Daniell.
5. Grenet.
6. Bunsen or Grove.
7. Magneto or dynamo machines.
8. Thermo-batteries.

USES CELLS ARE SUITED FOR.

STRONG, CONTINUOUS CURRENTS.

Electrotyping or Electro-plating	7, 4, 1, 3.
Electro-magnets	3, 4, 1.
Electric light	7, 6, 5.
Telegraph (closed circuit)	3, 4.

TEMPORARY.

Induction coils	5, 6, 4, 3.
Medical coils	5, 1,

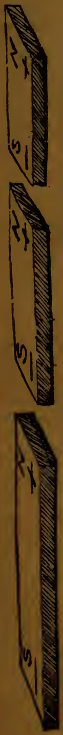
Occasional.

Annunciators, domestic bells	2, 1, 3, 4.
Exploding fuses	2, 4.
Electrical measurements (constant current)	8, 4, 3.

Table of Electro-Motive Forces.

Gravity or Daniell	0.98 to 1.08 Volts.
Bunsen and Grove	1.75 to 1.95 "
Leclanche, at first	1.48 to 1.60 "
Grenet "	1.80 to 2. 3 "
Smee	.65. — "

The force or current of the last three decreases considerably if the circuit is closed for a few minutes. These numbers signify, for instance, that it will require 195 Smee cells to give the same current in a circuit as would be given by 65 Grove cells.



From the foregoing table it will be seen that for constancy and durability the gravity battery is the best; but for strength of current and cleanliness the Grenet battery excels.

One of the most familiar pieces of physical apparatus is a magnet. We know how it can pick up bits of iron and steel. By the aid of a small instrument, mentioned before, we may make a pair of magnets and study there actions and laws. Take the electro-magnet, described in a previous article, and a couple of sewing needles or larger steel rods. Apply these needles, one at a time, to one end of the electro-magnet, and draw them several times across it from end to end, always in the same direction, and not rubbing back and forth. Repeat the operation with an iron wire of the same size; both the wire and the steel are attracted by the electro-magnet, but the iron wire more strongly. Observe that both, while in contact with the electro-magnet, possess the power of attracting bits of iron, but on removing them the steel is found to retain the property it had, while the iron does not.

Both of them exerted that peculiar force called magnetic force, or possessed the property called magnetism, that is, both were magnets; but as steel retains its power, it is called a permanent magnet, in distinction from a temporary magnet, like the iron wire or the electro-magnet itself. The quality of steel by which it at first resists the power of magnets, and resists the escape of magnetism which it has once acquired, is called coercive force. The harder steel is, the greater is its coercive force. Hence, highly tempered steel is used for permanent magnets. Hardened iron possesses some coercive force, hence the cores of electro-magnets should be made of the softest iron,

that they may acquire and part with magnetism instantaneously.

Suspend two magnets, each in a horizontal position, by threads that will not untwist, and several feet distant from each other. When they come at rest, notice that they have taken up a direction nearly north and south. Tie a thread on the end of each that points to the north.

This end, or pole, as it is usually called, we will speak of as the N-end, †, or marked end or pole, while the other is the unmarked—or S end or pole (see Fig. 2).

Now bring the marked end of one of the magnets near to the unmarked end of the other; they attract one another. Next bring the marked end of one near the marked end of the other; they repel one another. Bring the unmarked ends near one another; they repel one another. From this we discover the following law of magnets: Like poles repel, unlike poles attract one another.

Substances that are not susceptible to magnetism are, like glass, paper and wood, magnetically transparent. When a magnet causes another body, in contact with it or in its neighborhood, to become a magnet, it is said to induce magnetism in that body, *i. e.*, it influences it to be like itself.

As attraction, and never repulsion, occurs between a magnet and an unmagnetized piece of iron or steel, it must be that the magnetism induced in the latter is such that opposite poles are adjacent. Strew iron filings on a flat surface, and lay a box magnet on them. On raising the magnet it is found that large tufts of filings cling to the poles, as in Figure 3, especially to the edges; but the tufts diminish regularly in size from either pole toward the center, where none are found.

CHAPTER VI.

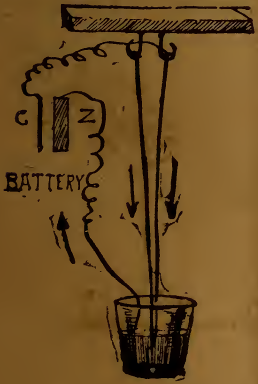
MAGNETISM.

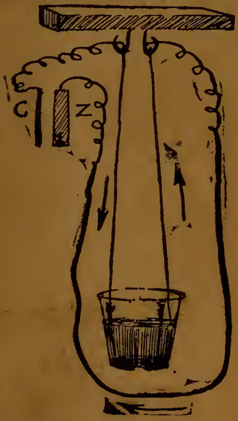
MAGNETIC attraction is greatest at the poles and diminishes toward the center, where it is nothing, or the center of the bar is neutral. The dual character of the magnet, as exhibited in its opposite extremities, is called polarity, and magnetism is styled a polar force. If a magnet is broken at its neutral line, as in the last article, it is found that equal and opposite polarities exist where there is ordinarily no evidence of them.

Place a copper wire through which a strong current of electricity is passing in a heap of iron filings, then raise the wire, filings cling to the wire somewhat as they do to a magnet, as shown in Figure 1.

This experiment and those with the electro-magnet and the deflection of the magnetic needle by an electric current, and a multitude of others that may be performed, cannot fail to convince that an intimate relation exists between electricity and

magnetism, which, though differing in many of their properties, yet alike in many, and almost invariably accompanying one another, and constantly merging one into the other, appear as if they were only different manifestations of one and the same agent.

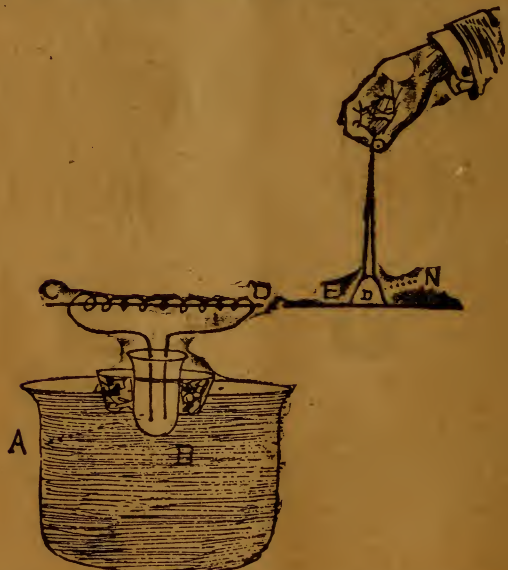




Suspend two copper wires (Fig. 2), each 12 inches long, and about 1-2 inch apart, with their lower extremities dipping about 1-4 inch into mercury, so as to move with little resistance either toward or from each other. Place one wire of the battery in the mercury, and attach the other to the hooks above. In Fig. 2 the current divides and flows down both wires to the liquid mercury, so that that part of the circuit presents parallel currents flowing in the same direction. Figure 3 is the same apparatus, with the connection so made that the current flows down one wire and up the other, and we have an

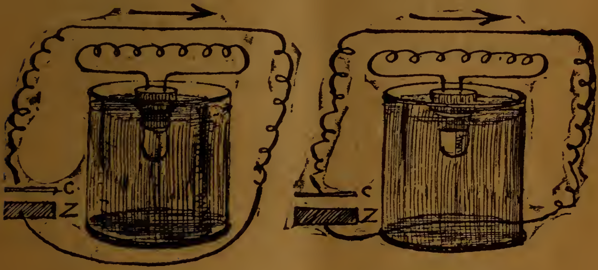
example of parallel currents flowing in opposite directions. In the former case the wires mutually attract one another. In the latter there is mutual repulsion. Hence we obtain the law. Parallel currents in the same direction attract one another; parallel currents in opposite directions repel one another.

An interesting illustration of the former part of this law can be arranged as in Figure 4. A battery wire is bent in the form of a spiral coil. At A the wire is broken, and one end dips just below the surface of mercury in a wine glass, while the other end is placed in the same liquid at a little distance from the first. When the circuit is closed the current will be parallel with itself, and will flow in the same direction in all parts of the coil that are adjacent. The attraction that follows will cause the coil to contract and lift one pole out of the mercury and break the circuit. The circuit being broken the attraction ceases, and the coil is drawn down



again by the force of gravity, and closes the circuit again; and thus constant vibratory motion is produced in the coil.

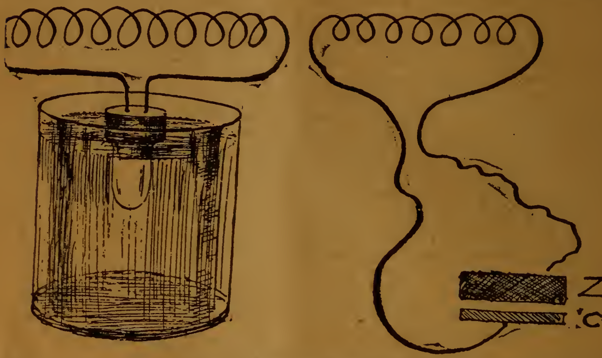
Prepare the following apparatus as represented in Figure 5. Through a cork A, 4 inches in diameter and 3 inches thick, cut a circular hole and insert a large-sized test tube B, about 6 inches long, that will just fit in the hole. Take an (No. 20) insulated copper wire about 6 feet long, wind the central portion into a coil C, with turns about 1-8 inch apart, leaving about 3 or 4 inches at both extremities unwound. To these fasten or solder pieces or strips of copper and amalgamated zinc as wide and long as the interior of the test tube will permit, and allow them to be separated. Insert them in the tube, and cover with dilute sulphuric acid (1 to 20). In the center of the coil lay a No. 16 soft iron wire D, and float the whole in a vessel of water. The apparatus constitutes a small floating battery and electro-magnet. Bring one end of a permanent magnet, or a short piece of soft iron wire E, suspended in a paper stirrup N, near to one of the poles of the core of the floating battery, and prove by experiment that the coil and its core behave in every respect like a magnet.



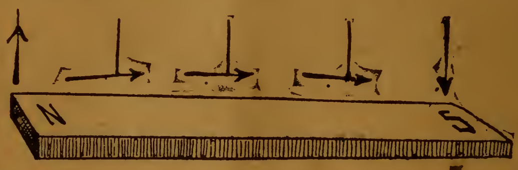
Remove the iron wire from the floating electromagnet and bring a separate battery wire over and parallel with the helix, as in Figure 6. In this position the two currents flow in planes at right angles to one another. Immediately the coil turns and tends to take a position at right angles to the wire above, so that the two currents may flow in parallel planes and in the same direction as in Figure 7. It will be observed that the action of the helix in the last experiment is analogous to the deflection of a needle by an electric current. Place opposite one end of the floating battery a second helix, Figure 8, in such a manner that the currents in the two helices may have the same direction. The two poles of the helices attract one another in conformity to the law previously mentioned. Reverse the poles of the helix in your hand so that the currents will flow in opposite directions, though still parallel; they repel one another.

The two helices appear to be polarized like two magnets, and for many purposes may be considered magnets. Observe that at one pole of each helix the current revolves in the direction

that the hands of a watch move, and at the opposite pole it revolves in a direction contrary to the movement of the hands of a watch. Bring the north pole of a box-magnet near that pole of the helix where the motion of the current corresponds to



the movement of the hands of a watch. They attract one another; but if the same pole of the helix is approached by the south pole of the magnet, repulsion follows. Hence, that is the south pole of a helix where the current corresponds to the motion of the hands of a watch (S), and that is the north pole where the current is in the reverse direction (N). But the important conclusion derived from these latter experiments is, that helices through which currents are flowing behave toward one another, or toward a magnet, in many respects as if they were magnets.



Magnetize a cambric needle. Suspend it by a fine thread attached to its middle over a magnet, and midway between its poles. The needle, however placed, immediately takes a position parallel with the magnet. The magnet exerts a directive influence on the needle.
Remove the magnet and the needle takes a northerly and southerly direction.

If you carry the needle all over your town or state, it will still maintain this direction. Something like the magnet exerts a directive influence on the magnetic needle.

Place the needle once more in its original position over the magnet, and gradually move it from the middle toward one pole of the magnet, the needle ceases to be horizontal. At either side of the center it dips; if it is nearer the N. pole of the bar, the S. pole dips, and conversely, as shown in Figure 9. If the needle is properly supported, the dip increases till at the poles the inclination is 90 degrees.

If a magnetic needle is freely suspended, and is carried to different parts of the earth's surface, it will dip as it approaches the polar regions, and is only horizontal at or near the earth's equator. A common compass-needle must have the S. end loaded to keep it horizontal. Like effects are commonly attributed to like causes. These phenomena are just what we should expect if (as is very improbable) a huge magnet were thrust through the axis of rotation of the earth; or if (as is more probable) the earth itself is a magnet.

Take a sheet of writing paper and strew iron filings lightly upon its surface. Place the poles of an ordinary horseshoe magnet beneath the paper and notice the result.

It is evident that the space a magnet is around the seat of a peculiar influence; this space, extending as far as the magnet exerts any effect, is called the magnetic field. The last experiment presents a true exhibition, on a small scale, of what the earth does on a larger one, and thereby presents one of many phenomena which lead to the conclusion that the earth is a magnet.

Hence it will be seen that the earth has poles just like any other magnet. Inasmuch as the magnetic poles at the earth do not coincide with the geographical poles, it follows that the needle does not in most places point due north and south. The angle which the needle makes with the geographical meridian is known as the angle of declination. This angle differs at different places.

As Columbus found, we can easily find the declination at any place as follows: Set up two sticks so that a string joining them points to the North Star; the string will lie in the geographical meridian. Place a long magnetic needle over the string; the angle between the needle and the string is the required declination. If great accuracy is required allowance must be made for the fact that the star is not exactly over the pole, but appears to describe daily around it a circle whose diameter is about four degrees.

The magnetic poles are not fixed objects that can be located like an island or cape, but are constantly changing. They appear to swing, something like a pendulum, in an easterly and westerly direction, each swing requiring centuries to complete it.

On the assumption that the earth is a ,magnet, it would not be strange if magnetizable substances should partake of its magnetic properties by induction. An ore of iron called lodestone, composed of a mixture of two oxides of this metal, possesses more or less magnetic power. Such magnets are termed natural magnets, to distinguish them from artificial magnets of steel.

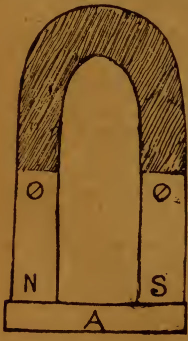
CHAPTER VII.

CURRENT INDUCTION.

THE cause of the earth's magnetism is not known. The theory that it is an electro-magnet in virtue of currents flowing around it near its surface from west to east explains all the effects that it produces on the magnetic-needle. But what sustains these electric currents? There are many things that point to the sun as the source of the earth's magnetism. Those who adopt this theory generally regard the terrestrial currents as thermo-electric.

A single instance will suffice to illustrate the intimate relation that certainly exists between the sun's condition and the earth's magnetism. In 1859 two observers, remote from each other, saw simultaneously a bright spot break out on the face of the sun, whose duration was only five minutes. Exactly at this time there was a general disturbance of magnetic needles and telegraph wires all over the world, being traversed with so-called earth currents. Telegraphers received shocks, and an apparatus in Norway was even set on fire. These phenomena were quickly followed by auroral displays. Sometimes telegraphs are worked by earth currents alone, without any battery in the circuit.

Artificial magnets, including permanent magnets and electro-magnets, are usually made in the shape either of a straight bar or of the letter U, called the "horseshoe," according to the use made of them. If we wish, as in the experiments already described, to use but a single pole, it is desirable to have the other as far away as possible; then obviously the bar-magnet is most convenient. But if the magnet is to be used for lifting or holding weights the horseshoe form is far better, because the attraction of both poles is conveniently available, and because their combined power is more than twice that of a single pole. This is due to the reflex influence of the poles on one another through the armature.

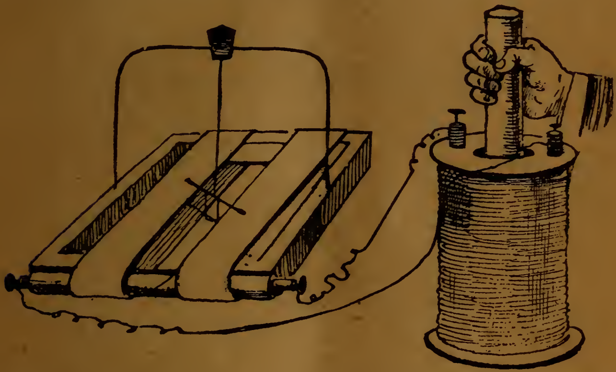


Magnets, when not in use ought always to be protected by armatures (A. Fig. 1) of soft iron for, notwithstanding the coercive power of steel, they slowly part with their magnetism. But when an armature is used, the opposite poles of the magnet and armature being in contact with one another, i. e., N with S, they serve to bind one another's magnetism.

Thin bars of steel can be more thoroughly magnetized than thick ones. Hence, if several thin bars (Fig. 1) are laid side by side, with their corresponding poles turned in the same direction, and then screwed together, a very powerful magnet is the result. This is called a compound magnet. In any magnet the outer layers are far more strongly magnetized than the central ones; so a steel

tube makes very nearly as strong a magnet as a rod of the same diameter, and is much lighter than the latter.

Perpetual motion seekers are easily led into the error of supposing that in the magnet they have an inexhaustible supply of energy; but a very little study will serve to exhibit the character of the error. If, for instance, we bring a piece of iron near a magnet, it is attracted, and, if allowed to move up to the magnet, this force of attraction will do a certain amount of work. Take now another piece of iron similar to the first; this also will be attracted, and a certain amount of work will be performed, but a less amount than that done in the first instance. Continue the operation until the magnet no longer attracts; then the magnet has done a definite amount of work, and lost the power of doing more. To restore it to its original condition, we must remove all the pieces of iron; this will re-



quire an expenditure of external work exactly equal to that originally performed by the magnet.

Thus far we have seen how currents of electricity are produced and how they are converted into magnetism. Now we will endeavor to explain how magnetism may be converted into electricity. In this fact alone lies the secret of all our late inventions, such as electric light, cable roads, etc.

Connect a helix with a delicate galvanometer (Fig. 2), and quickly thrust a magnetized steel rod into the coil. A deflection of the needle shows that a current of electricity at that instant traverses the wire. But the needle, after a few oscillations, assumes its original position. This shows that the current was only momentary; quickly remove the magnet; again the wire is traversed by a current, but this time in an opposite direction to the first, as shown by an opposite deflection.

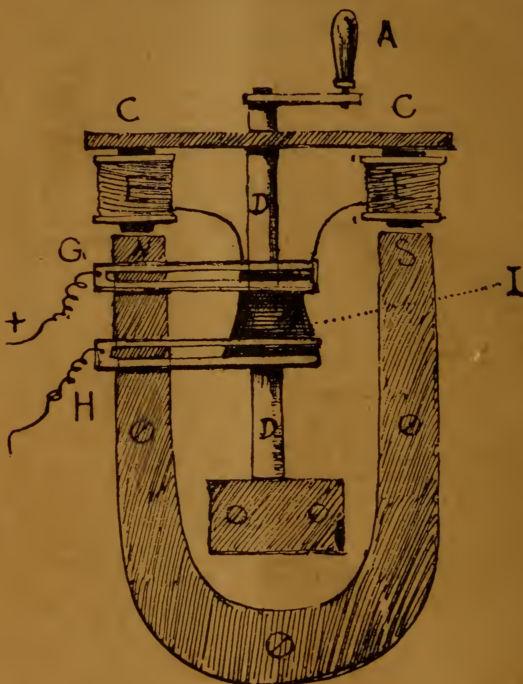
Place within the coil a core of soft iron. Wave back and forth, over one extremity of the core, one of the poles of a powerful bar-magnet. The needle of the galvanometer is violently

agitated, being deflected in one direction at each approach, and in the opposite direction at each departure. Now repeat the experiments with the opposite pole of the magnet. The effect is, as we should expect, to reverse all the currents.

If the permanent magnet is stationary, and the electro-magnet is moved back and forth, the result is the same as when the magnet was moved and the electro-magnet was stationary. Machines constructed for the purpose of generating electricity in this manner are called magneto electric machines.

Figure 3 will give a general idea of the construction of the simple kinds of magneto machines, such as are used in the telephone to ring the bells.

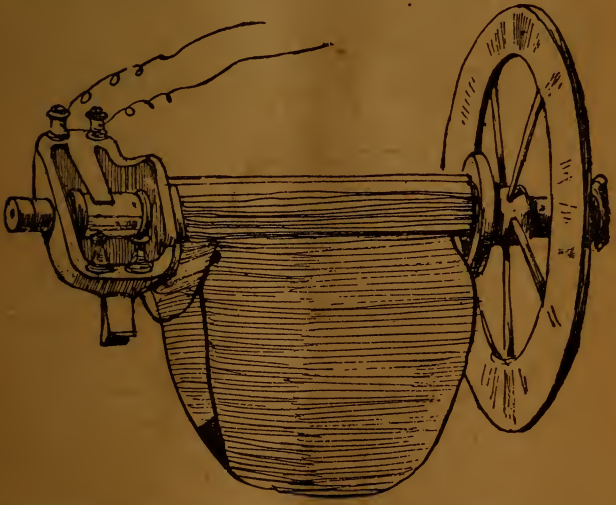
N. S. is a permanent magnet, composed of several horse-



shoe magnets screwed together. E. E. are coils containing rows of soft iron connected by the back armature C. C., the whole constituting a sort of an armature to the permanent

magnet. The brass axle D. D. is rigidly connected with the back armature C. C., so that when the axle is rotated by means of the crank A, both helices are carried around with it. Now, suppose the crank to be turned; during the first quarter of a revolution a separation of poles occurs, and currents of electricity are establishedin bothhelices. The wire that constitutes the helix is wound in *opposite* directions around the two cores, so that two currents may not flow in opposite directions through the wire, and thereby neutralize one another, but may have a common direction, and thereby produce a current of double the electro-motive force that would be produced in a single helix.

During the second quarter revolution the poles approach one another, and the effect would be to reverse the current; but the polarity of the wires also change, as they are now brought under the influence of the poles which they are approaching, and this double change leaves the current to flow in the same direcion as it did before. At the end of a half revolution there is a reversal of current, as the poles do not change at this point. The result would be that during every

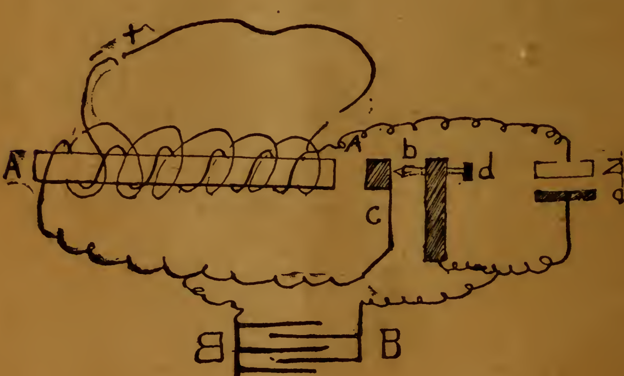


revolution there would be a current half of the time in one direction and half of the time in the opposite direction. In order to secure a constant current in one direction a current reverser, I, or *commutator*, as it is called, attached to the axle, is so arranged that the current is reversed at the end of each half revolution, and is then conducted away by the wires, G H.

In large machines electro magnets, excited by the main current itself, are used instead of permanent magnets, and thereby a greater inductive power and compactness are secured. Such a machine is called a dynamo-electrical machine, or often more briefly a dynamo (see Figure 4). The hand, or the steam engine, supplies the energy to revolve the magnets, and the product is electricity. The greater the mechanical power employed—in other words, the more rapid the revolutions, the greater the electro-motive force of the current produced. The electro-motive force varies also with the number of turns of wire in the coil used, and with the strength of the inducing magnets. The helix around the core may be made up of many turns of wire, if a high electro-motive force is desired to overcome great external resistance; or of fewer turns of larger wire if a small internal resistance is wanted, as for electro-plating.

When a very intense current is wanted an engine of eight or ten horse power is required. By means of the dynamo electric lighting, which formerly was considered a curiosity, has been reduced in expense so as to become a rival of gas lighting.

If a core of iron, or still better, a bundle of wire (AA. Fig. 5.) is inserted in the primary coil it is evident that it will be magnetized and demagnetized every time the primary is made and broken. The starting and cessation of amperian currents in the core in the same direction as the primary current, and simultaneous with the commencement and ending of the



primary current, greatly intensifies the secondary current. That is, if a coil of wire is wound around a core of iron and attached to a battery, another coil which is wound around the first in an opposite direction, but having no connection

with it, will be charged with a greater quantity of electricity than the first. This is called induction and the coil an induction coil. To save trouble in making and breaking the circuit by hand, as in Fig. 5, the core is also utilized in the construction of an automatic make-and-break piece. A soft iron hammer, B., is connected with the steel spring C., which is in turn connected with one of the terminals of the primary wire. The hammer presses against the point of a screw, D., and thus through the screw closes the circuit. But when the core becomes magnetized the hammer is drawn away from the screw and the circuit is broken. The circuit broken the core loses its magnetism, and the hammer springs back and closes the circuit again. Thus the spring and hammmer vibrate, and open and close the primary circuit with great rapidity.

Rhumkorff's coil, of which so much mention is made in Jules Verne's works, is an induction coil with the simple addition of a commutator, BB (see Figure 5).

The primary helices of induction coils consist comparatively few turns of coarse insulated copper wire; but the secondary helices contain many turns of very fine wire, insulated with great care. These coils develop a vastly greater current than can be obtained with the largest batteries. A coil constructed for Mr. Spottiswoode, of London, has two hundred and eighty miles of wire in its secondary coil. With fine Grove cells this coil gives a secondary spark forty-two inches long, and perforates glass three inches thick. Many brilliant experiments may be performed with these coils which have been indicated in connection with friction machines.

CHAPTER VIII.

USEFUL APPLICATIONS OF ELECTRICITY.

CURRENTS from an induction coil have great E. M. F., like frictional electricity, and so can pass through the poorly conducting tissues of the human body and produce violent muscular contractions. Currents induced by a single voltaic cell, through the mediation of an induction coil, may produce agonizing convulsions.

A voltaic current has a similar effect at the instants of making and breaking the circuit; but by beginning with a mild current, and slowly and gradually increasing its strength, a current from two hundred cells has been passed through a person with impunity. The physiological effect produced by an induced current at its negative pole is more violent than at the positive pole. In this way we may readily distinguish one pole from the other by simply holding one in each hand. The gradual current produces a benumbing influence, or insensibility to pain. A to-and-fro motion of the current produces a muscular agitation of the part through which it is sent, the tonic and stimulating effects of which are similar to those of muscular exercise.

The galvanic current also exerts a powerful electrolytic effect on the system. On this principle it has been successfully employed in reducing tumors, swellings, etc.

A platinum wire heated white-hot by a powerful galvanic current is used like a knife in surgical operations. The former has the advantage over the latter in that it sears the extremities of the blood vessels and thereby prevents hemorrhage. Enough has been said to show that a medical practitioner who can apply the laws of electricity has at his command a powerful therapentic agent; but except in experienced hands it is likely to prove useless, if not positively dangerous.

If the terminals of wires from a powerful magneto machine or galvanic battery are brought together, and then separated 1-20 in., the current does not cease to flow, but volatilizes a portion of the terminals. The vapor formed becomes a conductor of high resistance, and remaining at a very high temperature produces intense light. The light rivals that of the sun both in intensity and purity. The heat is so great that it fuses the most refractory substances, including even the diamond. Metal terminals quickly melt and drop off like tallow, and thereby become so far separated that the electromotive force is no longer sufficient for the increased resistance, and the light is extinguished. Hence, pencils of carbon (prepared from coke) which are less fusible, are used for terminals. For simple experiment, these pencils may be held in forceps (Fig. 1.) at the ends of two brass rods, to which the battery wires are attached. These rods slide in brass heads A and B supported by insulated pillars, to that the distance between the carbon points may be regulated. With the eight-cell Grenet battery, which I will shortly describe, this apparatus gives a beautiful illustration of the arc light, used in lighting streets.

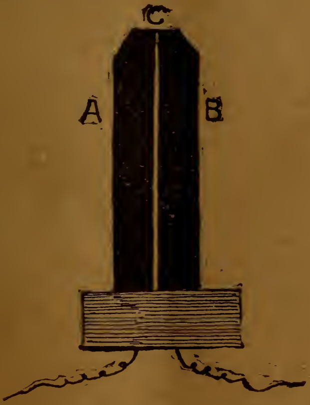
This light is too intense to be examined by the naked eye· but if the image of the terminals is thrown on a screen by means of a lens, or a pin hole in a card, an arch-shaped light is seen extending from pole to pole, as shown in Figure 2.

This light has received the name of the voltaic arc. The larger portion of the light, however, emanates from the tips of the two carbon terminals, which are heated to an intense whiteness, but come from the arc. The † pole is better than the — pole, as is shown by its glowing longer after the current is

stopped. The carbon of the † pole becomes volatilized, and the light-giving particles are transported from the † pole to the — pole, forming a bridge of luminous vapor between the poles. What we see is not electricity, but luminous matter. Neither light nor a current can exist with out matter, as may be shown by trying to pass a current between two metallic poles, a little way apart, in a charcoal vacuum; no spark can be produced.

It is apparent that the † pole is subject to a wasting away, and the — pole to a slight accession of matter. At the point of the former a conical shaped cavity is formed, while around the point of the latter warty protuberances appear. When, in consequence of the wearing away of the † pole, the distance between the two pencils becomes too great, the light goes out. Numerous self-acting regulators for maintaining a uniform distance between the poles have been devised. Such an arrangement is called an electric lamp. In some the carbons are worked by clock-work, which requires winding up occasionally; in others the movement of the carbons is accomplished automatically by the action of the current itself.

The "Jablockoff Candle" obviates all necessity for regulators. In this candle, instead of the carbons pointing toward each other, they are placed side by side, A and B (Fig. 3), separated by a thin insulating septum, C, of kaolin. The current passes up one carbon, across the space between the



points, and down the other. In its passage between the points it forms the luminous arc. The heat of the arc fuses and vola-

tilizes the kaolin, and it wastes slowly away like the wick of a candle; hence its name.

The electric light is of the purest white. In it the most delicate colors retain their noonday purity of tint, while a gas light appears of a sickly yellow hue in comparison. The average lamp burned on our streets is from 1,500 to 2,000 candle power.

But a still greater invention than the arc light is the incandescent electric lamp invented by Thomas Edison, the king of electricians. This is merely a piece of compressed carbon contained in a glass globe, from which the air has been exhausted.

Figure 4 represents a lamp of that kind of 2-candle power, i. e., will give as much light as two ordinary tallow candles. The current necessary to cause the carbon to become white heat, and thus give light, is 2 Volts (3 cells of Grenet battery.) Lamps of this kind are now made varying in candle power from 1-4 to 16 and 20. The 16-candle lamp is the one generally used to light store-rooms with, as this light is not so strong and does not affect the eyesight so much as the arc light.

I will now describe a powerful battery which anybody can make, and the cost of which will not exceed $1.50. This battery will light a 6-candle lamp for four consecutive hours, or, if not burned continuously, for a week, using it a short time each day. It will also perform all the experiments mentioned in these articles, and do any work that may be expected from a powerful battery. If attached to a large motor it will run a sewing-machine or a small express wagon on a board floor. Make two top pieces of inch pine board A. A. seven inches square (Fig. 5.) Buy also eight ordinary tumblers and eight pieces each of zinc and carbon.

Have the zincs and carbon cut 1-4 inch thick, 1 1-2 wide and 3 inches long. Amalgamate the zincs first by dipping them into dilute sulphuric acid (1 to 20 of water) and rubbing metallic mercury over them until they are coated with a bright silvery deposit. File a small nick into each corner of the zincs and carbons about 1-8 inch from the end and pass a few turns of No. 25 copper wire around them. Use the end of this wire to connect the elements together. Now set the elements on the board in the order given in the cut (c. z.), and fasten them down by means of strips of wood D, which should be nailed close to the carbon and zinc so as to hold them in place tightly. Bore small holes into the wood and pass through your copper wires which are attached to the carbons and zincs. Now take the wire from one carbon and attach it to the wire of the zinc in the next cell; take the carbon of this cell and connect it with the zinc of the next, so that when all are connected, you will have one carbon and one zinc left. These latter are the battery wires and must be attached to the copper washer of the binding post (F. Fig. 6). The zinc and carbon in each tumbler should be 3-4 inch apart, and the

elements of each cell should be 1 1-2 inches distant from those of the next cell. By using four binding posts, two on

each board, four cells may be used at a time; or, by using eight binding posts, two cells may be used at a time. Care, however, must be taken to connect the carbons with the zincs, otherwise there will be no current at all. Figure 6 is taken from a photograph of a battery of this kind, which I use for lighting a 6-candle lamp. The tumblers are placed in a pine box 9 inches high, 14 1-2 inches long and 8 inches wide.

The hooks, E, are fastened to both sides of the top board, and are turned out at right angles to the board, whenever it

is raised, so as to rest on the top of the box, thus keeping the elements out of the fluid and saving them from wastage. This should always be done. C represents a covered wire, which connects the electric lamp with the binding posts, F F. A lamp and stand of any candle power may be purchased for $1.50. This battery will burn two 2-candle lamps, four 1-candle lamps, eight 1-2 candle lamps, or one 6-candle lamp. If the fluid is pretty fresh it will burn an 8-candle lamp constantly for about one hour. After the battery has been made as described above, fill the tumblers almost full with the following battery fluid: Water, 2 quarts; common sulphuric acid, 6 oz.; bichromate of potassium, 8 oz. Add the acid to the water, and, after it has become cool, add the finely powdered bichromate of potassium. Whenever the battery is exhausted, a new fluid must be made, as the old one is entirely useless. After the fluid has been put into the tumbler, lower the top containing the elements and attach your wires to the electric light. The light will immediately burn, and continue so until the fluid is exhausted. The 2-candle lamp is small enough to be placed in the mouth, but care must be taken not to burn the tongue, as the glass becomes quite warm after burning for some time. In the next chapter I will describe a pocket battery and electric scarf-pin.

CHAPTER IX.

POCKET BATTERY AND MOTOR.

The battery described in the last article consisting of eight cells will answer for all experiments where a strong current is required. A small motor for running paste-board figures, etc., may be made in the following manner: Buy two electro-magnets (or make them yourself), and fasten the two wires nearest each other together. Mount them on a wooden base, and after having cut a Maltese cross out of a piece of soft iron, just wide enough to cover the core of the electro-magnets (C. Fig. 1), pass a thin iron spindle D through the cross, and hold in position by means of the piece of iron E. Fasten the two remaining wires of the electro-magnet to the binding posts F F. The battery wires must be attached to these posts, when the motor will run with surprising rapidity.

The above illustration will give a fair idea of how a motor should be made. If you cannot make one, you will be enabled to buy one of this kind for $1.50.

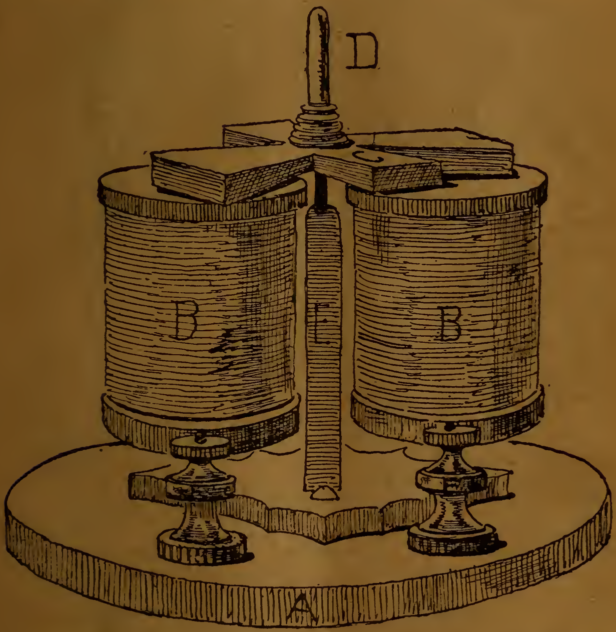
Figure 2 represents a small battery which may be concealed in any pocket and connected by means of an insulated double wire with a small 1-2 candle power electric lamp which is fastened to a cravat or scarf. The battery may be made as follows:

Take a piece of hard rubber four inches long and one inch wide, and fasten alternately two pieces of carbon and zinc (Fig. 3) 3-4 inch wide by 3 1-2 inch long, by means of screws to it.

Now purchase either a glass or rubber jar four inches long, four inches deep and one inch wide, and cement a piece of

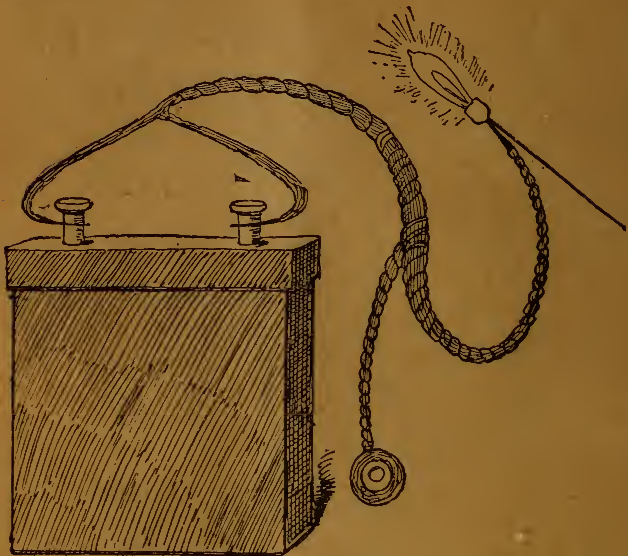
glass in the center, so as to divide the jar into two compart ments or cells. Fill the cells with the battery fluid mentioned in the last article and fasten the lid on the cell tightly, by means of strips of rubber laid between them, so as to prevent the fluid from being spilled upon the clothing. Connect the carbons with zincs, and the remaining carbons and zinc with the binding posts at the end of the lid.

Buy a one half candle power electric lamp and solder a darning needle to one of the wires (Fig. 2), connect the lamp with the battery by means of an insulated wire twisted into one cable.



The light may be started either by touching one of the wires of the binding posts, or by attaching a button to the battery wires by means of two short pieces of wire, which are made to rest in the arm-holes of the vest. The light should not be burned continuously, but flashed only at intervals; neither should the elements be allowed to remain in the solution when the battery is not in use, as they would soon be eaten up by the fluid. The entire cost of this battery and light, as described above, would be about $2.

Most books and periodicals are now printed from electrotype plates. This process is called electrotyping, and is done in the following manner:



A molding case of brass, in the shape of a shallow pan, is filled to the depth of about one centimeter with melted wax. A few pages are set up in common type, and an impression taken by pressing them into the wax.

The types are then distributed, and again used to set up other pages. Powdered plumbago is applied by brushes to the surface of the wax mold to render it a conductor. The mold is then flowed with alcohol to prevent the adhesion of air-bubbles, and afterward with a solution of copper sulphate, and dusted with iron filings, which form by chemical action a thin film of copper on the plumbago surface. The case is then suspended in a bath of copper sulphate dissolved in sulphuric acid. The — pole of a galvanic battery or magnetic machine is applied to it, and from the positive pole is suspended in the bath a copper plate opposite and near to the wax surface. The salt of copper is decomposed by the electric current, and the copper is deposited on the surface of the mold. The sulphuric acid appears at the X pole, and, combining with the copper of this pole, forms new molecules of copper sulphate. When the copper film has acquired the thickness of an ordinary visiting card, it is removed from the mold. This shell shows dis-

tinctly every line of the types or engraving. It is then backed with melted type metal to give firmness to the plate. The

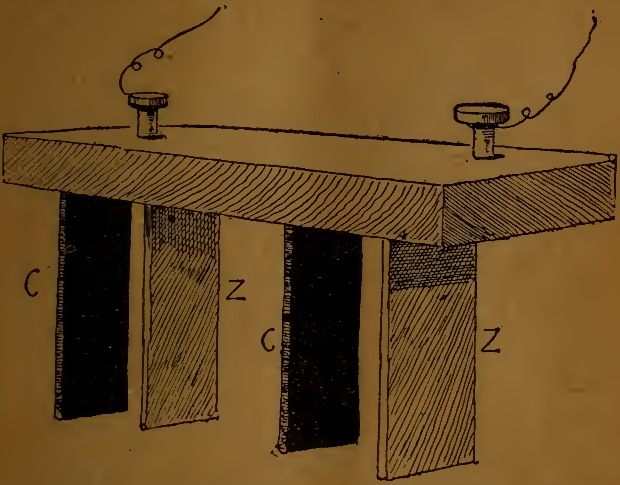
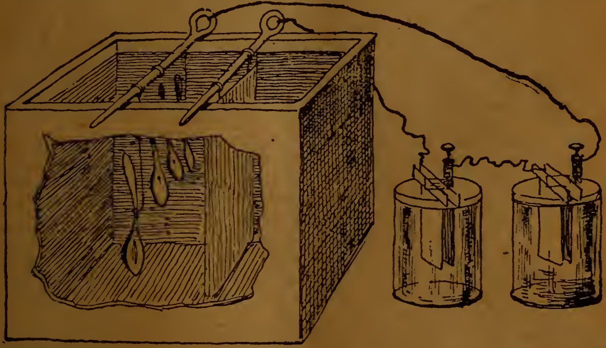


plate is then fastened on a block of wood, and thus built type high, and is now ready for the printer.

The distinction between electro-plating and electro-typing is that with the former the metallic coat remains permanently



on the object on which it is deposited, while with the latter it is intended to be removed. The processes are, in the main, the same.

The articles to be plated are first thoroughly cleaned and suspended on the — pole of a battery, and then a plate of the same kind of metal that is to be deposited on the given articles is suspended from the X pole (Fig. 4.) The bath used is a solution of a salt of the metal to be deposited. The cyanides of gold and silver are generally used for gilding and silvering.

Many of the base metals require to be electro-coppered first in order to secure the adhesion of the gold or silver. The magneto-electric machine has almost replaced the voltaic battery for electrotyping and electro-plating purposes.

For ordinary purposes, however, the Smee battery, which consists of two plates of zinc (Fig. 4), between which is a lead

plate covered with powdered platinum and immersed in a solution of one part of sulphuric acid to nineteen parts of water, is the best. Two cells are required to work properly. All articles that are to be plated must be thoroughly cleaned with acid, and must be free from grease.

The word *telegraph* literally signifies *to write far away*. In its broadest sense it embraces all methods of communicating thoughts with great speed to a distance by means of intelligible characters, sounds or signs; but usually it is applied only to electrical methods.

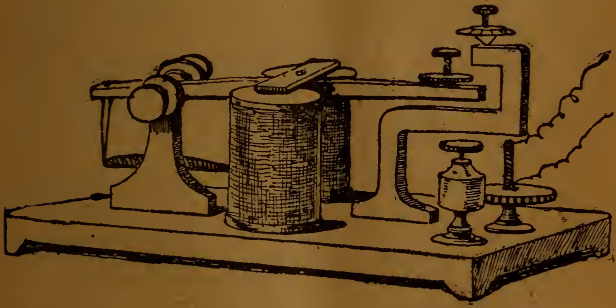
First, it should be understood that instead of two lines of wire, one to convey the electric current far away from the battery, and another to return it to the battery, if the distant pole is connected with a large metallic plate buried in moist earth, and the other pole near the battery is connected in a like manner with the earth, so that the earth forms about one-half of the circuit, there will be needed only one wire to connect telegraphically two places that are distant from each other. Furthermore, the resistance offered by the earth to the electric current is practically nothing, so that, disregarding the resistance of the ground connections, there is a saving of one-half the wire and one-half the resistance, and consequently one-half the battery power.

There are two ways of receiving a message—by means of

sound and by means of holes on a slip of paper. Let B, Figure 5· represent the message sender, or operator's key; Y the message receiver. It may be seen that the circuit is broken at B. Let the operator press his finger on the knob of the key. He closes the circuit, and the electric current instantly fills the wire from B to Y. It magnetizes A; A draws down the lever B, and presses the point of a style on a strip of paper, C, that is drawn over a roller. The operator ceases to press upon the key, the circuit is broken, and instantly B is raised from the paper by a spiral spring, D. Let the operator press upon the key only for an instant,.or long enough to count one, a simple *dot* or indentation will be made in the paper. But if he presses upon the key long enough to count three the point of the style will remain in contact with the paper the same length of time, and as the paper is drawn along beneath the point a short, straight line is produced.

This short line is called a *dash.* These dots and dashes constitute the *alphabet of telegraphy,* and this is the style of receiving by means of paper.

If the strip of paper be removed and the style is allowed to strike the metallic roller, a sharp click is heard. Again, when



the lens is drawn up by the spiral spring it strikes a screw point above, and another tick or click, differing slightly in sound from the first, is heard. A listener is able to distinguish dots from dashes by the length of the intervals of time that elapse between these two sounds.

Operators generally read by ear, giving heed to the clicking sounds produced by the strokes of a little hammer. A receiver so used is called a *sounder*, a common form of which can be seen represented in Figure 6.

In larger lines, where the current must travel miles of wire, a relay, which throws the circuit of the sounder on a local battery, is used. Otherwise the sounder would give either a very feeble or no sound at all.

The following is the alphabet and figures:

A	B	C	D	E	F	G	H	I
· —	— · · ·	· · ·	— · ·	·	· — ·	— — ·	· · · ·	· ·

J	K	L	M	N	O	P	Q
— · — ·	— · —	——	— —	— ·	· ·	· · · · ·	· · — ·

R	S	T	U	V	W	X	Y
· · ·	· · ·	—	· · —	· · · —	· — —	· — · ·	· · · ·

Z	&	,	?	.
· · · ·	· · · ·	· — · —	— · · — ·	· · — — · ·

1	2	3	4	5	6
· — — ·	· · — · ·	· · · — ·	· · · · —	— — —	· · · · · ·

7	8	9	0
— — · ·	— · · · ·	— · · —	——

CHAPTER X.

CONCLUSION.

In 1850 the practicability of conveying an insulated wire under water was proved by the laying of a single copper wire, insulated with guttapercha, between Dover and Calais, which continued in operation for one day. A heavier cable, containing four wires, was subsequently submerged at the same place, and continues in operation to this day.

About 300 cables of various styles of manufacture have been laid in different parts of the world, varying from three cables each of 2,000 miles length, joining Europe to America, to the numerous short lengths which now unite the western islands of Scotland with the mainland. The cables laid in the earlier years passed through many vicissitudes, and have entailed great loss from imperfect insulation, mishap in submersion, and other causes.

The Malta-Alexandria cable, laid in 1861, and which continued in use for eleven years, was the first long cable constructed with a careful regard to its electrical and mechanical conditions, and it corresponds very closely with the best form of cable now made.

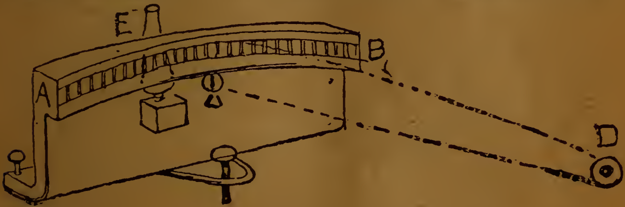
About thirty different forms of cable have been made, lighter cables being made for temporary use or for still water, while the heavier cables, carefully tested in every stage of manufacture and submersion, are intended for deeper or stormier seas.

In the longest submarine lines it was found that only a weak current was received at the distant end, and in order to secure the action of the current a more delicate instrument than any in use must be provided. This was found in the beautiful invention or adaptation by Sir William Thomson, of the Reflecting Galvanometer. Figure 1 shows the principle of this instrument. In the figure, D represents a short magnetic needle suspended by a silk fiber, and having attached to it a small mirror. Needle and mirror together weigh about a grain and a half. By means of a lamp a pencil of light is thrown upon

the graduated index, A B, a movement of this image to one side or other being made to represent the dots and dashes of the Morse alphabet. To give steadiness to the needle it is brought to rest by a magnet after each deflection.

By an enlargement of the graduated scale some very delicate illustrations of electric action can be given. Thus, to show that dissimilar metals plunged in the same liquid will evolve electricity, the wires leading to the galvanometer may be joined up to a steel knife and a silver fork, and on fixing the fork into a piece of raw meat the light on the scale will be sensibly depleted at the instant the knife is brought also in contact with the meat. A cell consisting of a copper percussion cap with a small morsel of zinc has been found to create sufficient electricity to send a message across the Atlantic.

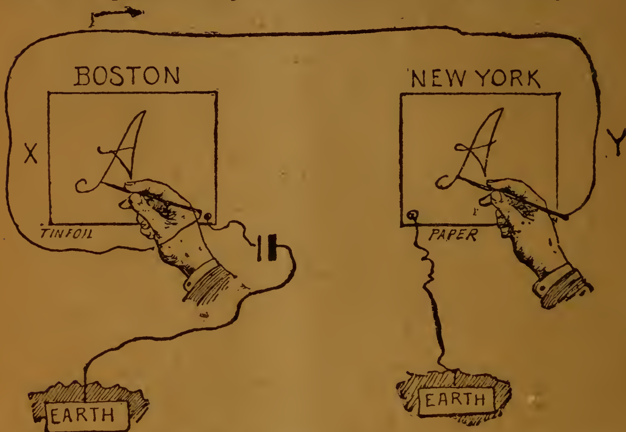
In his *Ink-recorder*, Sir William Thomson has given another beautiful adaptation of electric science. A fine coil is sus-



pended between the poles of a fixed magnet, and attached to the coil is one limb of a small glass syphon, the other end of which dips into a vessel containing ordinary ink.

So long as no current passes the ink flows from the syphon in a straight stream, making a mark on a paper tape which runs below. But on the coil being attracted to either side by the passage of an electric current, the ink work waves from side to side, the deflections serving as the dots and dashes of the Morse rods. Fac-simile telegraph is an autographic apparatus, by means of which a message may be, practically, transmitted over a wire and appear at a distant terminus in the exact handwriting of the sender and ready at once for delivery. The principle on which it works may be learned from Figure 2, in which all the details of its mechanism are omitted for simplicity of illustration. X is a sheet of tin-foil, on which the message to be sent is written with an ink prepared by dissolving sealing-wax in alcohol. The alcohol quickly evaporates, leaving the lines of sealing-wax adhering to the foil. Y is a sheet of paper moistened with a solution of prussiate of potash. Each of the pens is simply a small, pointed iron needle. Now, suppose that both of the pens are moved at the time and with the same rapidity across their respective sheets. The electric current, decomposing the prussiate of potash, will cause the needle in New York to trace a continuous blue line on Y, until the needle in Boston reaches a line of sealing-wax on X, when the circuit is

broken as it passes over this line. At the same time there is a break in the continuity of the line traced on Y. If, further, each needle is moved down a hair's breadth each time it traverses its respective sheet, then we shall have an exact facsimile of the writing on the tin foil produced on the chemically-prepared paper, except that whereas the original is written in dark letters on a light ground, the message is received in light letters on a dark ground. Pen and ink sketches of photographs and other pictures may be transmitted in the same way.

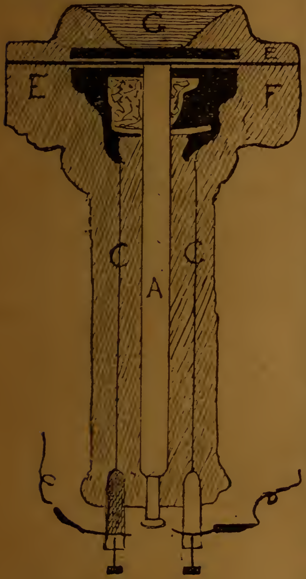


The pens are not, of course, held and guided by human hands, but by complex machinery. The rigorous exactness requisite in the movement of the two pens is secured by the absolute synchronisms in the vibration of two pendulums, one at each terminus, controlled by the electric current.

Figure 3 represents a sectional view of the Bell telephone. It consists of a steel magnet, A, about five inches long and three-eighths of an inch in diameter, encircled at one extremity by a short bobbin, on which is wound a coil, B, of very fine insulated wire; the ends of the coil, C C, are connected with the binding screws, D D. Immediately in front of the magnet is a thin, circular iron disk, E E. The whole is inclosed in a wooden or rubber case, F, with the exception that the wood is cut away at G, so as to expose one surface of the iron disk. The conical-shaped cavity serves the purpose of either a mouth-piece or an ear trumpet. There is no difference between the transmitting and receiving telephone; each instrument is in itself a diminutive magneto-electric machine, and so, of course, no battery is required in the circuit. Connect in circuit two such telephones by two wires, or employ the earth for one of the conductors, and the apparatus is ready for use.

When a person talks to the disk of the transmitter, he

to the magnet, is itself a magnet by induction; and, as it throws it into rapid vibration. The disk, being quite close vibrates, its magnetic power is constantly changing, being strengthened as it approaches the magnet, and enfeebled as it recedes. This fluctuating magnetic force will, of course, induce currents in alternate directions in the neighboring coil of wire. These currents traverse the whole length of the wire, and so pass through the coil of the distant instrument. When the direction of the arriving current is such as to reinforce the power of the magnet of the receiver, the magnet attracts the iron disk in front of it more strongly than before. If the current is in the opposite direction the disk is less attracted and flies back. Hence, whatever movement is imparted to the disk of the transmitting telephone the disk of the receiving telephone is forced to repeat. The vibrations of the latter disk become sound in the same manner as the vibrations of a tuning fork or the beat of a drum—but this explanation would belong to the science of acoustics or sound.



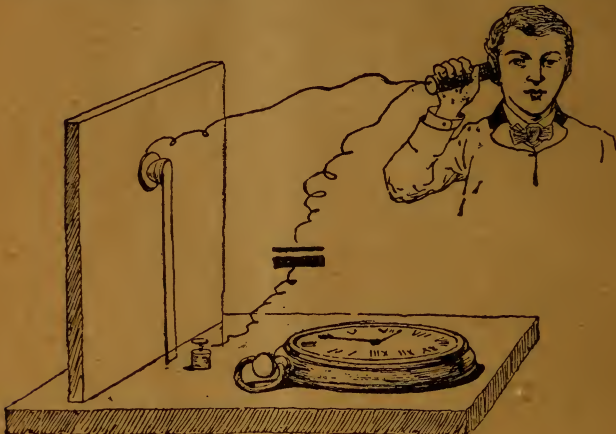
The Microphone, although of little use practically, is still a great curiosity scientifically, and can easily be made by a good mechanic. In figure 4, A and B are buttons of carbon; the former is attached to a sounding-board of thin pine wood, well seasoned, the latter to a steel spring C, and both are connected in circuit with a battery and a telephone, used as a receiver. The spring presses B against A, but any slight jar will cause a variation of the pressure. The reader must have learned ere this that the effect of a loose contact between any two parts of a circuit is to increase the resistance, and thereby weaken the current; but the effect of a slight variation in pressure is especially noticeable when either or both of the parts are carbon. Now any slight jar, as that caused by the tick of a watch, will cause a variation in the pressure between the carbon buttons, and this will produce a corresponding variation in the current, and the fluctuations in the current are attended with the usual vibrations in the telephone receiver.

By means of this instrument, called *microphone*, any *little sounds*, as its name indicates, such as the ticking of a watch

or the footfall of an insect, may be reproduced a considerable distance, and be as audible as though the original sounds were made close to the ear. If a person talk to the thin pine board, his words will be distinctly heard in the receiver.

The last subject which we will consider is the *Storage* or *Secondary* battery.

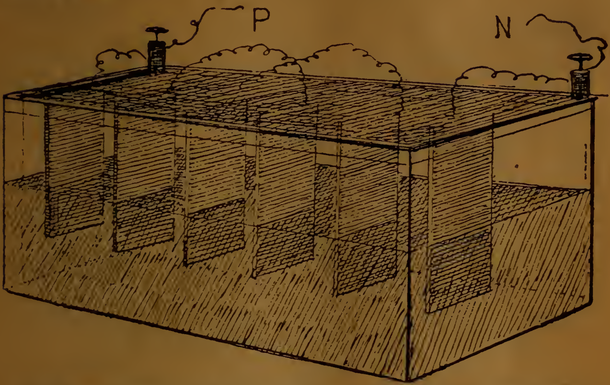
A Storage battery consists simply of two lead plates immersed in a solution of sulphuric acid and water (water 10 parts, acid 1 part). Figure 5 represents a jar containing the elements ready for use.



Take a piece of pine wood three inches wide by four inches long, and fasten to it six plates of sheet lead, two inches wide by three inches long, about half an inch apart. Connect the second plate with the fourth, and the third with the fifth; this leaves the first and sixth, which are positive and negative respectively. Place these in a square glass or earthen jar three inches wide, four inches long, and four inches deep; place into the jar the solution and fasten the top on tightly. The elements nor the solution need not be changed at all, as they waste away very slowly.

In order to charge the battery connect its two wires to the wires of the 8-cell battery described in another article, and allow them to be in circuit for two hours. Disconnect them, and the battery is ready for use, and must be handled the same as any other battery. This single cell will burn a 2-candle lamp for one hour. After the battery is discharged, attach it again to the 8-cell battery for two hours, and it will be as fully charged as the first time. If the top is properly sealed, the battery may be carried in the pocket. In conclusion I would state that if you fail to reach any result the first time you try any of

these experiments, try it over again and you will succeed better than at first.

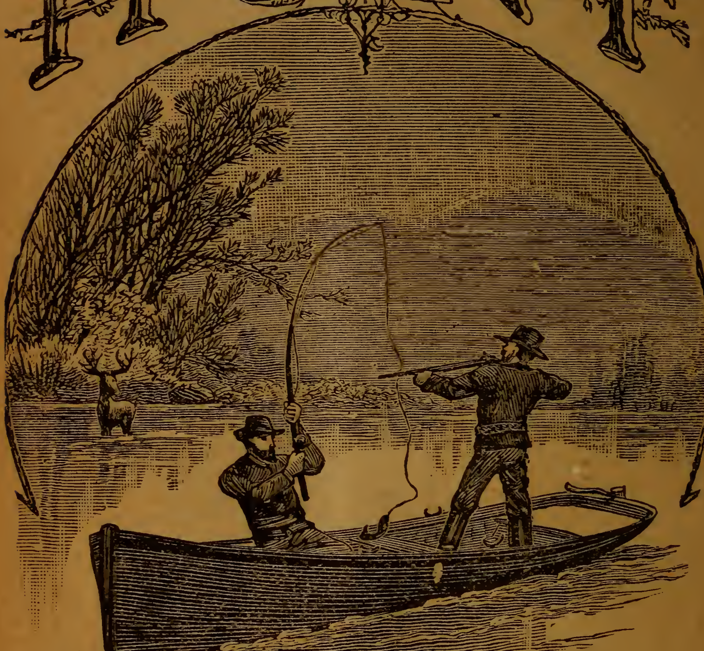


Great care must be taken to have all wires and connections *properly insulated*, and you will find that many a failure is referable to the neglect of this precaution. All materal used should be *dry* and *clean*; dirt and moisture are good conductors. If you are unable to make one part of an apparatus, you may save a great deal of worry and time by purchasing the same at a low price from some dealer in such articles. Instruments of this kind are *very* expensive, but *single parts* are *very*

cheap, and with a little ingenuity combined with directions found in these articles, you will be enabled to make, in miniature, almost any instrument now in use. I would, however, caution all to be careful with the acid mentioned in connection with batteries. Should any of it be spilled on clothes, it will ruin them entirely, leaving yellow spots.

[THE END.]

HOW TO HUNT



AND FISH